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Comparison of Long View Radiography Systems

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1. Introduction

With the arrival of an aging society has come an increase in the need for long view radiography examinations. Long view radiography was previously limited mainly to cases of degenerative scoliosis, but is now used for all spinal diseases that cause spinal deformity as well as for postoperative assessment and preoperative planning for the replacement of weight bearing joints in the lower extremities. Long view radiography currently plays an important role in the field of orthopedic medicine. Long view radiography is used with a total spine frontal view to measure Cobb angle, with a lateral view to measure PI and C7-CSVL, and with a total lower extremities frontal view to measure the Mikulictz line. The demand for long view radiography is increasing due to its usefulness in visualizing areas within a single image that a conventional 14 × 17 inch cassette size could not. Within this context, a variety of methods of acquiring images from long view radiography are being made available. At present, the main acquisition methods are full irradiation, X-ray tube rotation, SLOT radiography, and collimation, with each manufacturer implementing long view radiography by a different method in each of their products. This article will compare each type of long view radiography system used at our hospital with Shimadzu's SONIALVISION safire series.

2. Methods of Long View Radiography

This section will briefly describe the methods of image acquisition of each long view radiography method.

(1) Full irradiation

This method uses a conventional film/screen system or computed radiography (CR). Radiography is performed with the X-ray tube fixed in one position and irradiation performed once onto either two 14 × 17 inch cassettes or three 14 × 14 inch cassettes **(Fig. 1 (a))**. With this method, the exposure time can be short so body movement has little effect on the image.

(2) X-ray tube rotation

The X-ray tube rotates around a fixed focal point and radiography is performed multiple times on a movable flat panel detector (FPD) **(Fig. 1 (b))**. Characteristics of this method are the absence of correction during image reconstruction since the angles of irradiation incidence are equal at the joints between each image. Although, just as with the full irradiation method, the angle of incidence is large at the top and bottom edges of the image, which means there is often distortion in the image and the radiography distance must be lengthened.

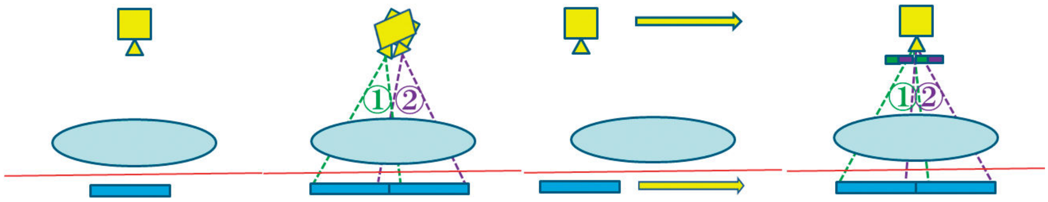
(3) SLOT radiography

Radiography is performed through a collimator while the X-ray tube and FPD move together in parallel at a fixed speed **(Fig. 1 (c))**. A characteristic of this method is that distortion-free images can be obtained at every part of the image, including the top and bottom edges, since the angle of X-ray incidence is almost perpendicular to the FPD. In addition, the exposure speed can be adjusted to accommodate whether image quality or exposure time is the more important parameter in a certain situation.

(4) Collimation

Radiography is performed multiple times while varying the irradiation field by moving the FPD and changing the collimator, while the X-ray tube stays at a fixed position and angle **(Fig. 1 (d))**. This method is simple mechanically as the X-ray tube does not require a driving motor. The images obtained are similar to those obtained using the X-ray tube rotation method.

We operate the systems shown below at our hospital.
- CR system ((1) full irradiation))
- General radiography system A from company A ((2) X-ray tube rotation)



(a) Full irradiation (b) X-ray tube rotation (c) SLOT radiology (d) Collimation

Fig. 1 Long View Radiography Methods

General radiography system B from company B
((2) X-ray tube rotation)
X-ray fluoroscopy system C
((2) X-ray tube rotation, (3) SLOT radiography)
SONIALVISION ((3) SLOT radiography)

We examine each of these systems in this article. Note that since our hospital has no system performing radiography by the collimation method (4), the collimation method will not be covered in this article.

3. Matters Examined

The following differences became apparent while performing long view radiography with multiple systems.

(1) Exposure time and image visualization time

The time from the start to the end of X-ray irradiation (exposure time) and the time from the end of exposure to when the long view image has been created (image visualization time).

(2) Inconsistencies in image reconstruction

Inconsistencies that arise during the visualization of a single long view image reconstructed from data comprising multiple images. Also, measuring precision in terms of apparent point-to-point distance in the long view image when there is inconsistency.

(3) Overlap where images are joined

Depending on the system and exposure conditions, how much overlap occurs when an image is reconstructed from multiple images.

(4) Differences due to SLOT radiography reference height

When reconstructing an image from SLOT radiography data, the height from the table surface (reference height) of the main observed area must be set correctly. This is to correct the degree of image enlargement, as well as discontinuities where the images are joined together, which are caused by differences in the angle of X-ray irradiation during data acquisition while the X-ray tube moves parallel with the FPD. We examined the effect of sub-optimal reference height settings on the final image.

(5) Other

Effects on image quality when changing the exposure speed for SLOT radiography, effects of correcting for body movement during reconstruction, and the effects of afterimages during serial radiography.

This article reports on our examination of items (1) through (4).

4. Results

(1) Exposure time and image visualization time

The exposure times for each long view radiography system were measured for an irradiation range of around 100 cm. After CR, the quickest exposure time was nine seconds achieved by system A and SONIALVISION in High Speed (HS) mode **(Fig. 2 (a))**. The exposure times of all other systems and radiography modes were 16 seconds or more. At this length of time, we must consider the effects of body movement on the image and the ability of the patient to hold their breath.

The shortest image visualization time was eight seconds for system A **(Fig. 2 (b))**. The image

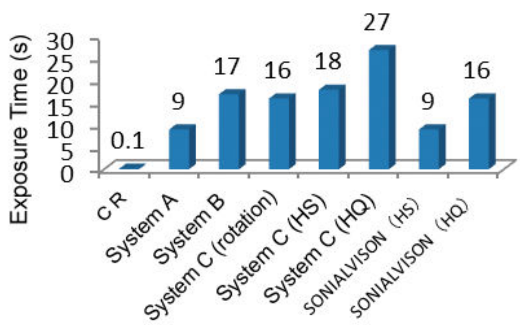


Fig. 2 (a) Radiography Time

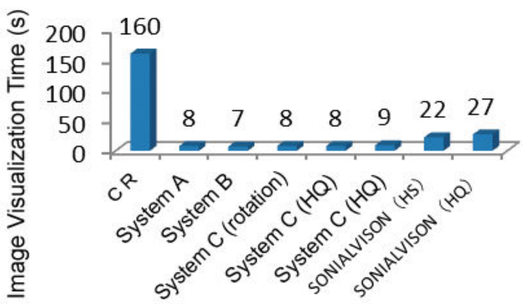


Fig. 2 (b) Image Visualization Time

visualization time for SONIALVISION was 20 seconds or more. Compared to an image visualization time of less than 30 seconds for FPD-equipped systems, the image visualization time with CR was much longer at 160 seconds because of the work handling a set of three 14 × 14 inch cassettes entailed. The post-exposure processing time was short for systems A, B and C at around 10 seconds, which is likely to contribute to improved throughput.

Considering just the FPD-equipped systems, the image visualization time for SONIALVISION was 20 seconds or more but only around 10 seconds for all other systems. We would like to see improvements made to SONIALVISION that create a slightly shorter time to image visualization.

Considering the time from starting exposure to image visualization, we found that system A was the quickest overall, followed by SONIALVISION HS mode that had a total examination time of around 30 seconds. These results point to improved throughput compared to use of CR.

(2) Inconsistencies in image reconstruction

We performed radiography on a phantom body with a measuring stick placed inside it **(Fig. 3 (a))** and checked for inconsistencies in the automatically reconstructed long view images of each system **(Fig. 3 (b))**. We measured a point-to-point distance along the measuring stick in the reconstructed image at the top, middle, and bottom of the image for a measure of precision **(Fig. 3 (c))**. We found a high degree of precision in the SONIALVISION image with a point-to-point measurement of 50 mm according to the imaged measuring stick equaling 50 mm in real terms. CR also produced a highly precise reconstructed image with almost no displacement. All systems using X-ray tube rotation were likely to exhibit some displacement in the reconstructed image, and to require some manual image reconstruction as necessary upon visually checking the imaged measuring stick.

A substantial error appeared when performing measurements through PACS with systems B and C, the cause of which was poor calibration. We confirmed at a later date that measurements could be made where imaged dimensions were close to actual dimensions.

(3) Overlap where images are joined

We set the irradiation range to 100 cm and measured the length of overlap where images are joined **(Fig. 4)**. Overlap with CR was 30 mm, with X-ray rotation method systems B and C the overlap was 50 mm or more, and with SONIALVISION and system C (SLOT radiography) while the amount of overlap varied depending on the image reconstruction menu options selected, overlap of 20 mm to 40 mm occurred. CR radiography is performed once only with no repeated exposure, but with X-ray tube rotation and SLOT radiography exposures overlap in multiple locations, and consideration must be given to the occurrence of overexposure.

(4) Differences due to SLOT radiography reference height

By changing the reference height set value, we verified the continuity of substances placed at different heights from the table surface, and the precision of the imaged point-to-point distance. A measuring stick and acrylic rod were placed at 0 mm and 200 mm heights on the SONIALVISION table and radiography was performed with a SID of 120 cm and 150 cm, each in HS and HQ mode. We then reconstructed the data obtained at 0 mm, 100 mm and 200 mm reference heights and measured the precision in each image **(Fig. 5)**.

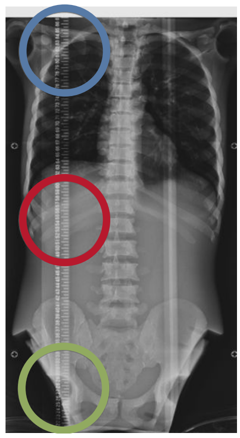


Fig. 3 (a) Image with Measuring Stick

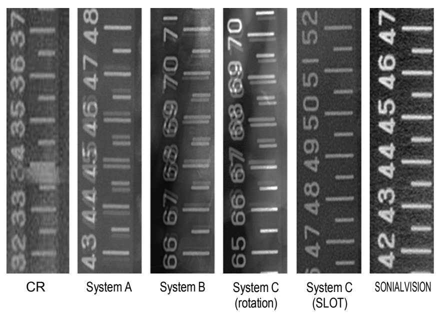


Fig. 3 (b) Measuring Stick Images (showing the red circle in **Fig. 3 (a)**)

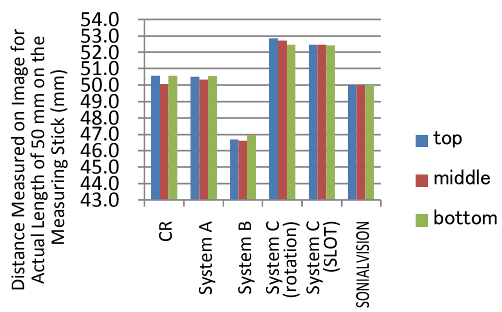


Fig. 3 (c) Distance Measured on Image for Actual Length of 50 mm on the Measuring Stick

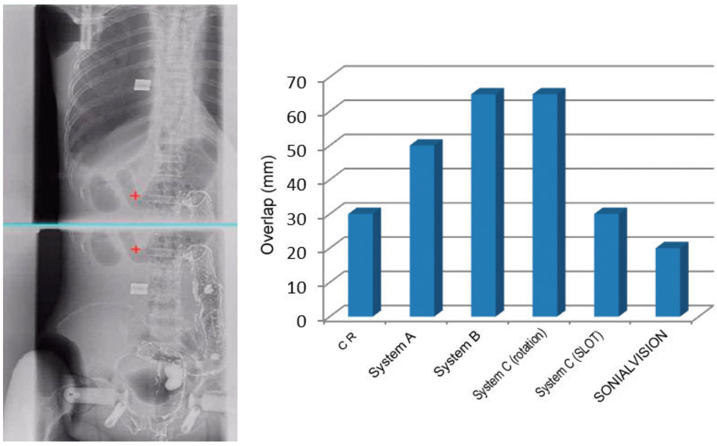
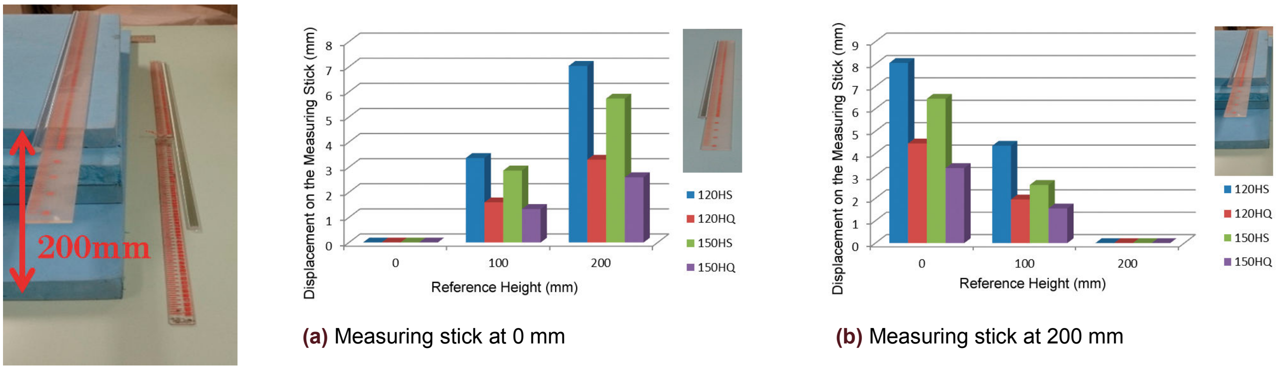


Fig. 4 Overlap Where Images Are Joined

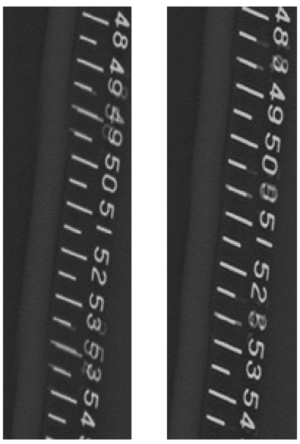


(a) Measuring stick at 0 mm

(b) Measuring stick at 200 mm

Fig. 5 Displacement due to Reference Height

Continuity and point-to-point measurement precision were high when the reference height and actual height were the same. However, when the actual height and the reference height were largely different, for example, when the measuring stick and acrylic rod at 0 mm height and the reference height at 300 mm, there was a marked decrease in continuity and the precision of the imaged point-to-point distance **(Fig. 6)**. In addition, with SONIALVISION we found the error to be twice as large in HS mode compared to HQ mode. In light of this result, we believe that performing image reconstruction with the reconstruction position as it appears in system presets is likely to create an image that differs from the true image, and it is necessary to measure the actual distance of the main target from the table and enter this value prior to reconstructing the image.



(a) HS **(b)** HQ

Fig. 6 Incorrect Reconstruction
(Displacement of 10 mm in HS mode and 5 mm in HQ mode)

5. Case Examples

We will show a case example of a patient that underwent SLOT radiography with CR, SONIALVISION, and system C **(Fig. 7)**. CR images underwent image processing using multifrequency processing, where the C7 vertebra and femur heads can be verified. Using system C the pelvis appeared faint while the cervical vertebrae appeared with high density enough to make a clinical assessment of the case difficult. With the lateral view imaged using SONIALVISION there were artifacts caused by primary rays, making femur head assessment difficult though cervical vertebrae assessment was possible. In this case, the patient had undergone THA of the left hip joint and artifacts were apparent due to inclusion of the artificial hip joint in the irradiation range. Such artifacts are not normally present with SONIALVISION, and images can be obtained that allow assessment of the femur heads.

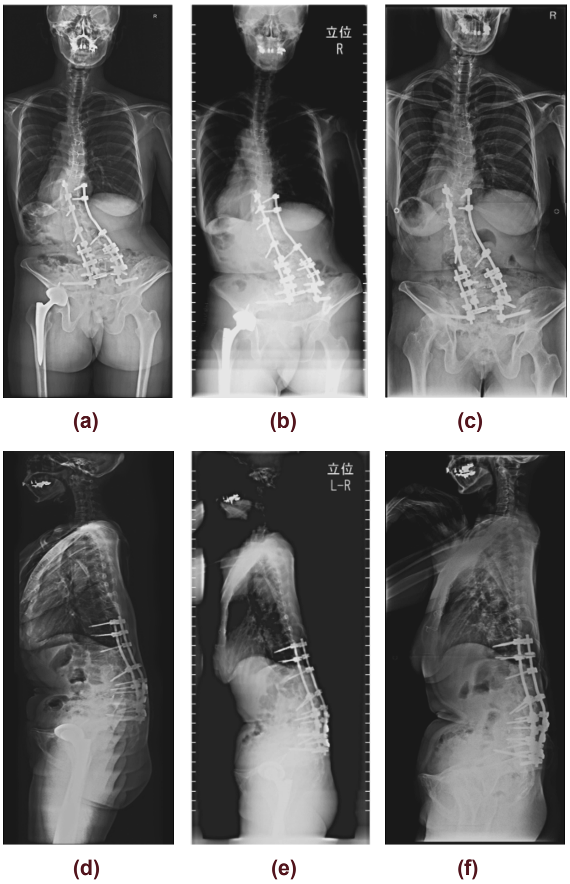


Fig. 7 Total Spine Case Example
(a) SONIALVISION **(b)** System C (SLOT) **(c)** CR
(d) SONIALVISION **(e)** System C (SLOT) **(f)** CR

6. Conclusions

In this article we compared a number of long view radiology systems. We were impressed by the processing speed of the FPD-equipped systems. FPD-equipped systems are actually useful as they can improve examination throughput as a replacement for CR, where image visualization can take two minutes or more. We compared SLOT radiography using SONIALVISION to CR and X-ray tube rotation radiography systems and found we can obtain images with reduced distortion in the longitudinal direction with SONIALVISION as the incident X-rays are almost perpendicular to the detecting surface and collimation is also used. While the exposure time of SONIALVISION is longer than CR, when the breath holding time and throughput improvements are taken into account, SLOT radiography with SONIALVISION can be considered more useful than the other radiography systems we examined.